

Chapter 2 - Geophysical

This chapter provides baseline information, key findings, and identifies key issues associated with the physical characteristics of the Pierre area. Information documented in this chapter will be used as a basis for influencing planning policy decisions in formulation of the Comprehensive Plan.

Understanding an area's physical environment is an integral component of proper long-range land use planning. The physical environment's geology, soils, hydrology, and climate all shape an area's growth patterns. The following chapter summarizes the important attributes of the City's natural environment, allowing City officials, land owners and citizens an understanding of those natural characteristics enhancing future development, while also drawing attention to the problematic natural characteristics of the landscape so they can be proactively addressed.

Topography

Pierre is located in central South Dakota, very near the geographic center of the state, and along the northeastern banks of the Missouri River. The City is located in the Great Plains physiographic region (Figures 2.1) and more specifically the Coteau du Missouri physical division. The Coteau du Missouri, meaning "hills of the Missouri," is a highland area covered with glacial outwash deposits and underlain by Pierre shale and older formations (Malo 1997). The older part of the City is located in the Missouri River Valley and most of the newer development is located beyond the rim of the Valley. The terrain varies from flat river bottom land, to gently sloping hills, to steep ravines and washes. The topography ranges from 1420 feet above sea level at the Missouri River to 1742 feet above sea level at the airport and to 1810 at the Snake Butte ridge. The relative slope for the City is illustrated in Figure 2.2.

Pierre is partly located along the floodplain of the Missouri River, which is relatively flat and contains some gently sloping terrain with 20 to 30 feet of relief. The remainder of the City occupies the shale bluffs along the River which rise as much as 160 feet above the floodplain. The natural topography provides an aesthetically pleasing and variable landscape with many desirable vistas.

The resulting topography provides natural positive drainage between the higher elevations and the river channel and reduces the poor drainage issues often faced by areas with limited topographic relief. The area's topographic relief and steep slopes cause issues relating to erosion control, increase the speed of storm water runoff, and amplify the storm water volume that accumulates in the low-lying areas.

The biggest drainage challenge facing the Pierre area is the resulting high-velocity storm water flowing down the steep slopes and the subsequent erosion and detention concern. In general, those areas identified in Figure 2.2 with slopes greater than 6% are more susceptible to erosion control and runoff issues.

The area's topography also impacts the cost for road, sewer, water and utility expansions. The slopes can make road construction and utility expansion more difficult and costly, and in some cases even cost prohibitive because of the higher installation cost and greater engineering requirements needed to cope with the topography. The added costs to expand services through areas of the City with steep slopes and great topographic relief will likely influence the location of future development.

Geology and Soils

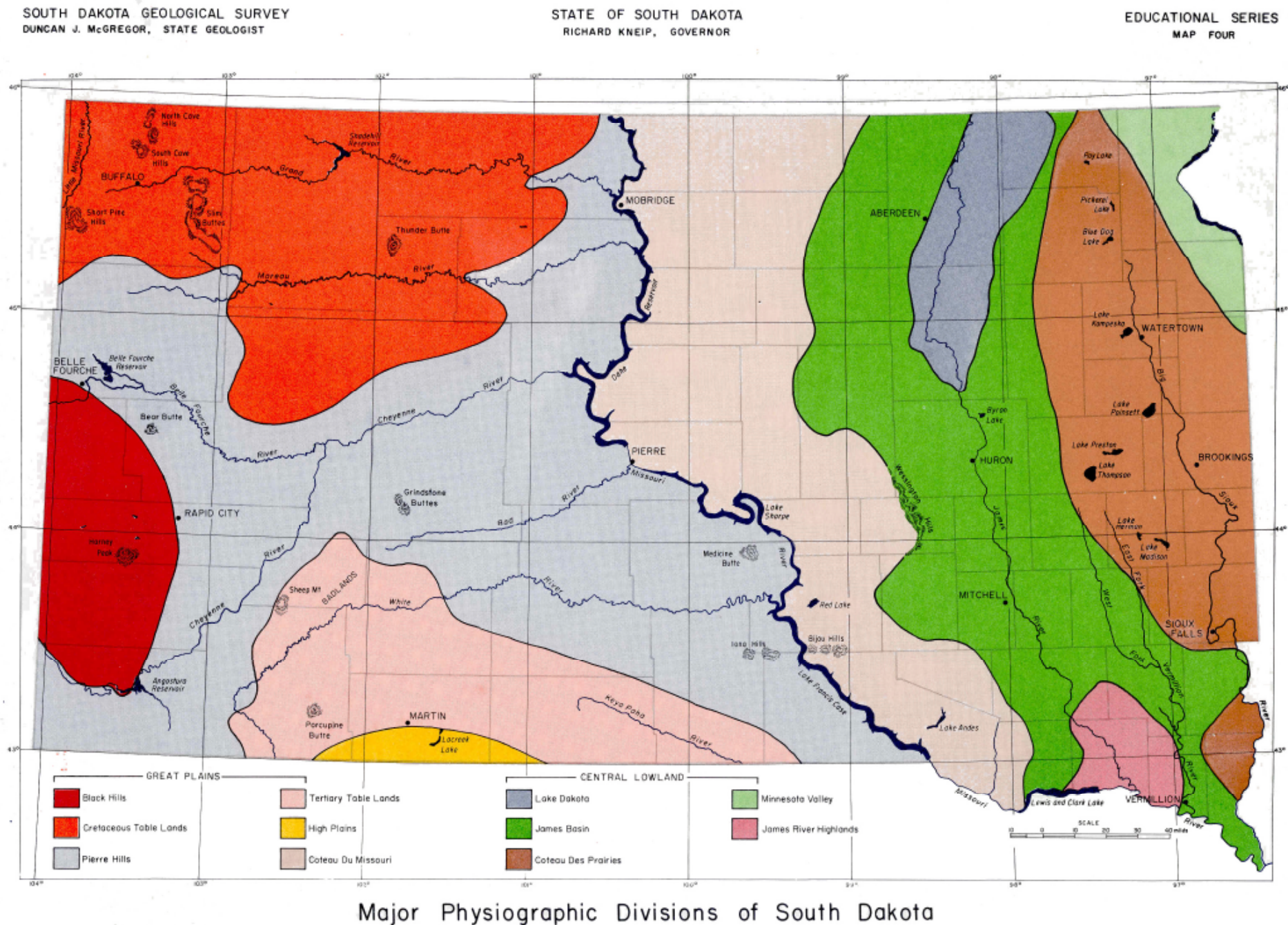
The geology and soils of the Pierre area also influence the potential for development. The characteristics of the soils generally limit the agricultural utilization to uses such as grazing for most of the area. The engineering characteristics limit the potential for development in some parts of Pierre because of the potential for structural failures.

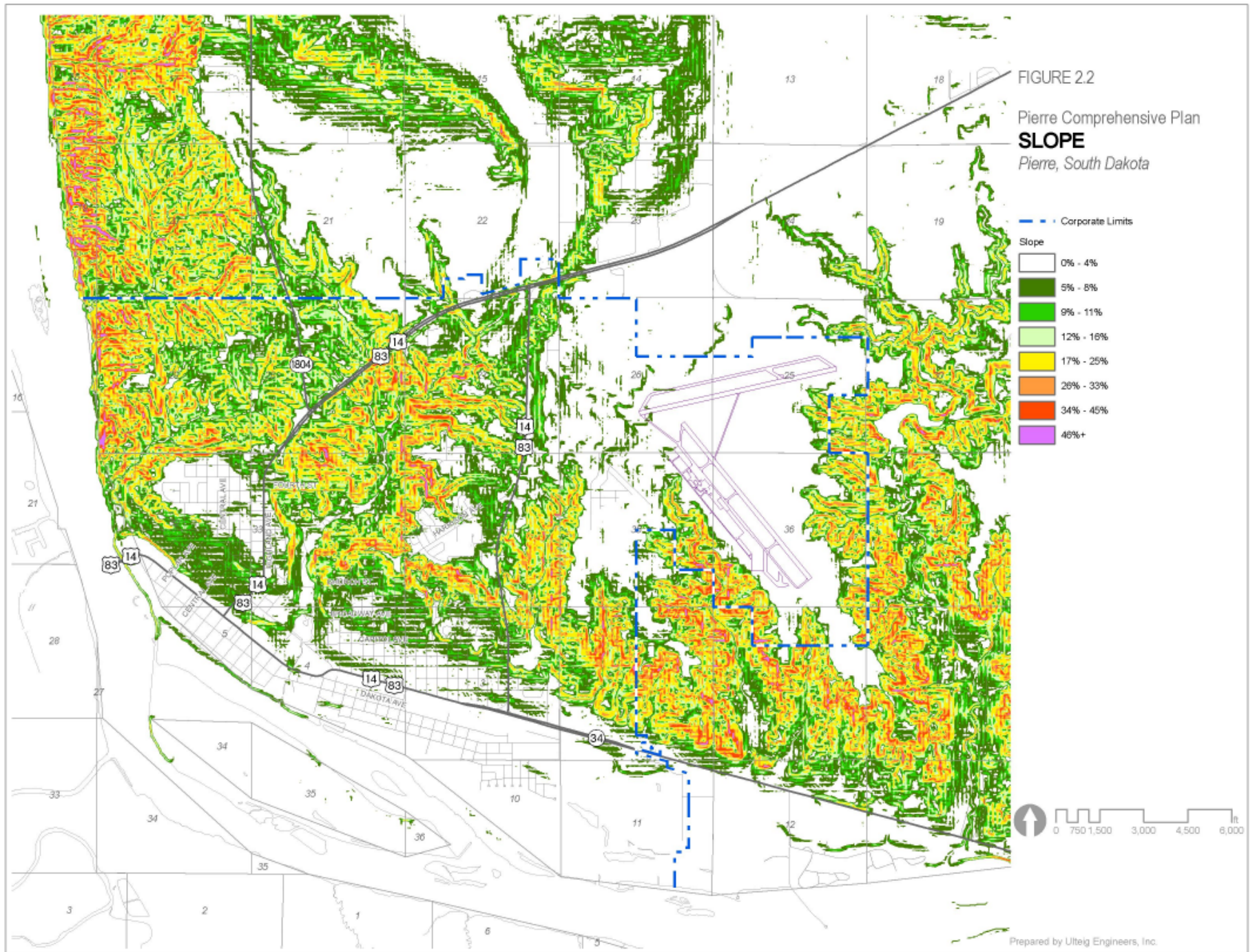
Agricultural-based Soils

There are four (USDA-NRCS) primary soils types in the Pierre area: Munjor, Lowry-Agar, Gettys-Betts, and Highmore-Eakin

These soils each have different capabilities to support different functions. Table 2.1 illustrates the capabilities of these soil types in the Pierre area.

Figure 2.1. Physiographic Divisions of South Dakota (SD Department of Environment and Natural Resources)





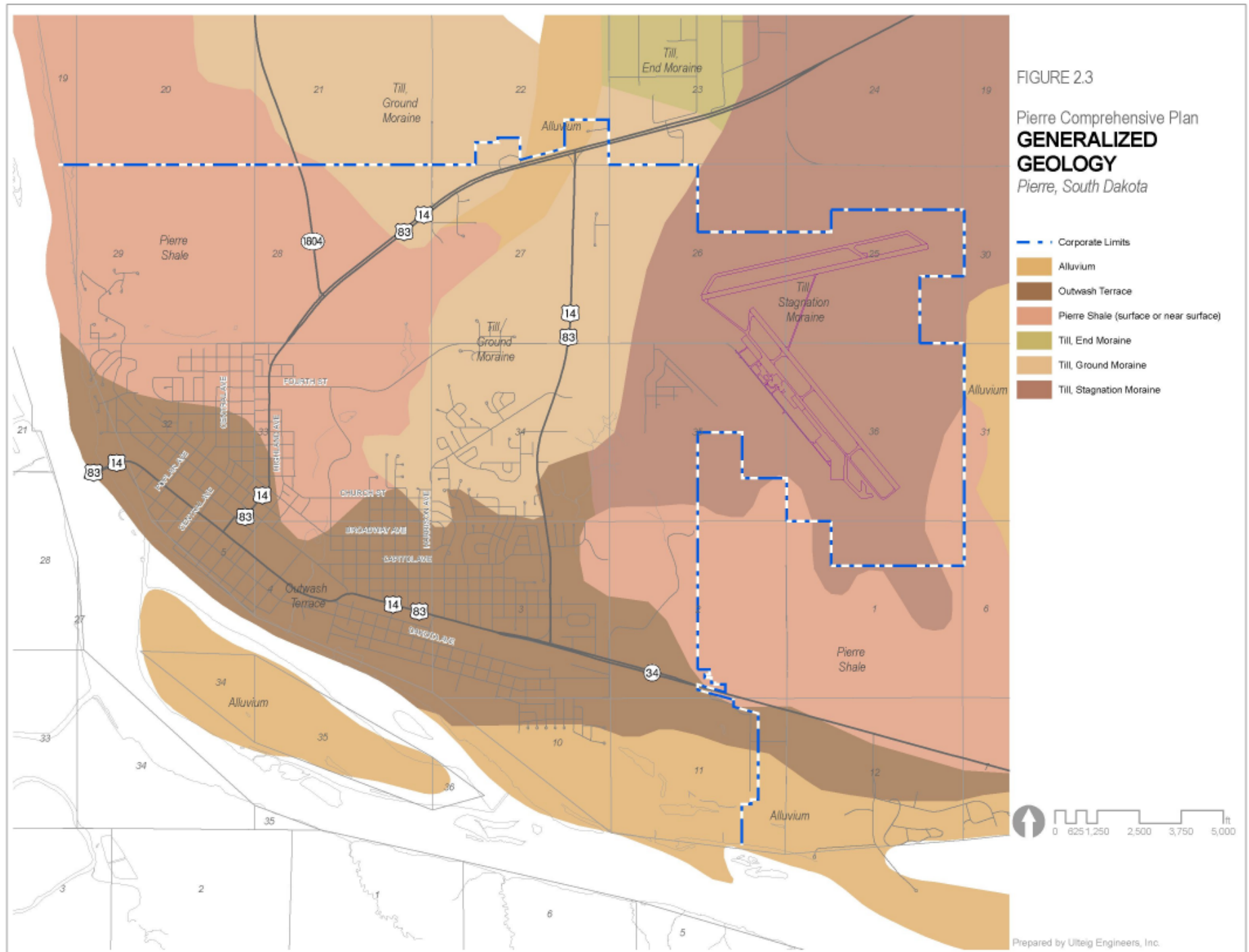


Table 2.1. Official series descriptions (USDA-NRCS 2004).

Munjoy Series	
Thickness	Deep
Landform	Low terraces/flood plains
Slope	0-2%
Drainage	Well drained or moderately well drained
Runoff	Low
Conductivity	High
Use	Most areas are cultivated-grain, wheat, alfalfa
Crops	Grain sorghums, winter wheat, and alfalfa
Native Vegetation	Mixed grass prairie

Lowry Series	
Thickness	Very deep
Landform	Nearly level to strongly sloping uplands and terraces
Slope	0-15%, typically less than 6%
Drainage	Well drained
Runoff	Low to high
Conductivity	Moderate
Use	Used about equally as cropland and rangeland
Crops	Winter wheat, oats, grain sorghum, corn, and alfalfa
Native Vegetation	Western wheatgrass, bluegrama, needleandthread, and green needlegrass

Agar Series	
Thickness	Very deep
Landform	Nearly level to moderately sloping uplands
Slope	0-9%, commonly are less than 2%
Drainage	Well drained
Runoff	Low on nearly level slopes and medium on more sloping areas
Conductivity	Moderate
Use	Mainly cultivated
Crops	Grain, corn, sorghums
Native Vegetation	Green needlegrass, western wheatgrass, needleandthread, blue grama, big bluestem, little bluestem, sedges, and forbs

Gettys Series	
Thickness	Deep or very deep
Landform	Undulating to steep on uplands in rolling to hilly glacial moraines and side slopes of drainageways
Slope	6-45%
Drainage	Well drained
Runoff	Rapid
Conductivity	Moderately slow or slow
Use	Used almost exclusively for native range
Crops	
Native Vegetation	Little bluestem, sideoats grama, western wheatgrass, blue grama, and needleandthread

Munjoy Series	
Thickness	Deep
Landform	Low terraces/flood plains
Slope	0-2%
Drainage	Well drained or moderately well drained
Runoff	Low
Conductivity	High
Use	Most areas are cultivated-grain, wheat, alfalfa
Crops	Grain sorghums, winter wheat, and alfalfa
Native Vegetation	Mixed grass prairie

Betts Series	
Thickness	Very deep
Landform	Undulating to very steep on uplands in rolling and hilly glacial moraines and side slopes of drainageways
Slope	2-60+%
Drainage	Well drained
Runoff	Medium to very high
Conductivity	Moderate in upper part and moderately slow in underlying material
Use	Principle use in native range, but some areas are cultivated
Crops	Small grains, corn, and other feed crops
Native Vegetation	Needleandthread, blue grama, big bluestem, little bluestem, green needlegrass, western wheatgrass, plains muhly, and sideoats gama

Highmore Series	
Thickness	Very deep
Landform	Nearly level to undulating uplands
Slope	0-9%
Drainage	Well drained
Runoff	Surface runoff is slow on nearly level landscapes and medium on more sloping areas
Use	Mainly cultivated
Crops	Winter wheat, alfalfa, corn, grain sorghum, and oats are the main crops
Native Vegetation	Western wheatgrass, needleandthread, green needlegrass, big bluestem, and blue grama.

Engineering Geology

There are three soil groups that affect construction of private and civil works projects in the Pierre area. Construction may encounter terrace alluvial gravels near the Missouri River in the lower elevations of Pierre while glacial surface soils are encountered above the terrace gravels. Depending on the topography and past erosion, bedrock Pierre shale

may be encountered at any elevation in the Pierre area. In general, glacial derived soils such as sandy soils and pebbly silt clays present minimal construction problems. Wind deposited Loessial soils with high silt content can, under certain conditions, affect construction. Deposits of loess are rather small and are found in outcrop at the western bluffs of Pierre and on scattered locations over the higher elevations. As clay content increases in soils, a potential for construction problems multiplies.

Soil moisture greatly affects the engineering properties of clay soils. Increases or decreases in soil moisture severely affect the strength, swell and shrinkage of high-content clay soils. This is especially true with Pierre shale as it normally has a high expansive clay content. Some till soils can contain remnants of Pierre shale that make them moderately expansive. Many of the soils encountered in the Pierre area fall into an expansive category. Assistance by engineers is sometimes required in the planning and construction of private and civil works in the Pierre area.

Geologic Constraints

Surficial deposits, the stratigraphic layer found between the bedrock and soil layer, in the Missouri River floodplains are the result of glaciation and recent stream deposits by the Missouri River since the retreat of the last Wisconsin ice sheet. These deposits (Figure 2.3) consist of glacial outwash and alluvium. The alluvium deposits consist of silt to pebble-size fragments and range in thickness from a few feet to [about 75 feet]. Glacial outwash consists of coarse sand to cobble-size gravel; the thickness is not known, but the material lies inconsistently on the shale bluffs adjacent to the Missouri River (Brinkley 1971). Two members of the Pierre Formation of Cretaceous age are exposed along the bluffs of the Missouri River in the Pierre area: the Verendrye Member, consisting of olive-gray mudstone and siltstone and DeGrey Member, consisting of siliceous shale and claystone with bentonite beds (Crandell 1954). Subsurface bedrock in the area consists of sedimentary rocks of Cretaceous age present beneath the exposed bedrock and in descending order: Pierre Shale, Niobrara Marl, Carlile Shale, Greenhorn Limestone, Graneros Shale, Dakota Formation, Skull Creek Shale, and Inyan Kara Group. The Sundance underlies the Lakota sandstone and below this formation are Paleozoic rocks that overlie Precambrian basement rocks (Figure 2.4) (Brinkley 1971). However, only the Pierre formation is exposed in the Pierre area.

Figure 2.4. Stratigraphic column of the subsurface bedrock (Brinkley 1971).

Period	Section	Formation	Description
Mesozoic Era	60 Million Years	Pierre Shale	150 to 240 feet thick. Light-to dark-gray clayey shale.
		Niobrara Marl	125 feet thick. Marl containing many shaley layers.
		Carlile Shale	310 to 400 feet thick. Light-gray to black shale interbedded with silt and sand.
		Greenhorn Limestone	50 feet thick. Hard, light-colored limestone, with some siltstone and shale.
		Graneros Shale	285 to 340 feet thick. Dark-grey clayey shale.
		Dakota Formation	58 to 92 feet thick. Alternating sand, sandstone, and shale beds.
		Skull Creek Shale	30 to 60 feet thick. Medium-to dark-gray shale; glauconitic silt horizon near the center.
		Inyan Kara Group (Fall River and Lakota Sandstone)	115 to 180 feet thick. White to light-gray, fine-to medium-grained sand.
		Sundance Formation	40 feet thick. Green shale and thinly bedded sandstones.
Paleozoic Era	180 150 120 Million Years		
Precambrian Era	3 Billion		Stratified Paleozoic rocks underlain by Precambrian quartzite or granite.

Slope stability and Landslides. The major geologic hazard for the Pierre area is landslides resulting from the Pierre Shale underlying geological material (Figure 2.3 & 2.4). Pierre Shale is susceptible to slumping because of the numerous thin bentonite layers that have large swell potential and greasy texture when wet. These natural characteristics of the soil, and formation properties such as joints, fractures, and faults, result in a soil very susceptible to slumping (Duchossois 1993).

As previously mentioned, Pierre shale clays are highly susceptible to changes in water content. Most landslides and slumps in the Pierre area can be attributed to a change in moisture content and/or a change in surface loading. Slides and slumps have damaged structures and roadways in Pierre and were the result of one or several of the following: over-loading the top of a slope, construction of non-compacted fills, excavating out the base of a slope, constructing over old slumps (lack of a proper foundation), constructing fill over seeps of groundwater or improper diversion of surface water flow. All of these potential problems can be addressed with proper engineering and planning. A careful review of aerial photography of the area reveals many cases where slumping or slides have occurred. Figure 2.5 illustrates an example of this characteristic. The areas outlined in red are old slump blocks. The areas outlined in blue are seeps. The green lines indicate areas where the top of Pierre shale was cut and pushed over the edge of a bluff without proper compaction. This results in buried slump blocks and seeps leaving the edge of these bluffs prone to failure.

Historically, several severe failures have occurred in recent decades leading to structural damage of buildings in the Pierre area. In 1977 failure did occur on this site (Figure 2.5) causing the destruction of basements and the loss of lots. Two houses (A & B) were eventually moved. The second house (B) was not built at the time of this 1975 photograph. House C was moved before damage occurred. Structures have been moved off of Herseth Drive, North Madison Avenue, River Place Drive, Buffalo Street, and Norbeck Drive.

Seismology. A seismic or earthquake hazard in the Pierre area is almost non-existent. The Pierre area falls within the seismic design category A of the 2003 International Residential Code. Categories are on a scale of A (minimal risk) through E (major risk).

Figure 2.5. Example of Slumping Surficial Soils of the Pierre Area (Vern Bump)



Surface and Ground Water

All water for the Pierre area is derived from precipitation; either as recharge of ground water via rain or melting snow infiltrating the water table or the recharge of bedrock aquifers from precipitation outside the area or the inflow of the Missouri River supplied by sources of precipitation upstream. Normal annual precipitation is 19.8 inches and approximately 75% of the annual precipitation falls during the growing season. The area's high summer temperatures which can exceed 100°F, and its windy conditions, can necessitate the need for irrigation to supplement the natural precipitation (Hamilton 1986a). Shallow groundwater percolating through surficial glacial soils, or through discontinuities in the Pierre shale, are corrosive to metals. In some cases, the strength of concrete may, with time, be affected by corrosive groundwater. These waters do not support active vegetative growth.

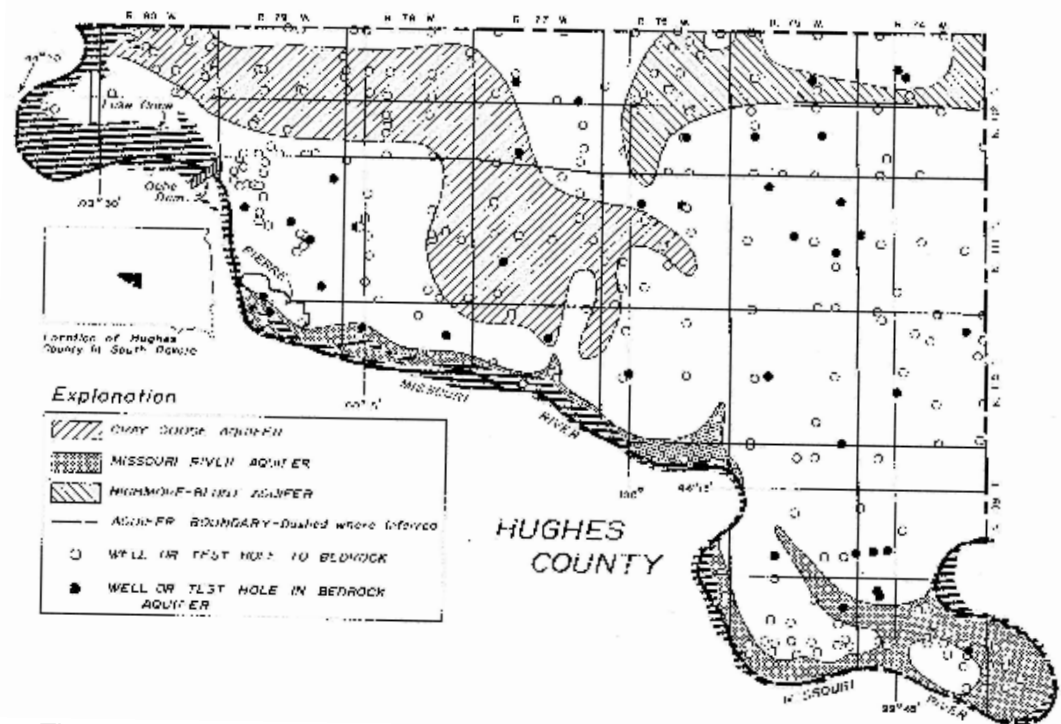
The Missouri River and its Oahe reservoir, both in volume and potential for development, vastly overshadow all other sources of surface water in the area (Hamilton 1986a). The flow of the Missouri River at Pierre is controlled by releases of water from Lake Oahe for power generation and other purposes. The mean daily releases from Oahe range from less than 1,000 cubic feet per second (cfs) to 57,000 cfs (USACE 1999). The Bad River flows into the Missouri River from the west across from the northwestern end of LaFromboisie Island.

The Pierre area has one underlying glacial aquifer: the Missouri River; and three bedrock aquifers: the Dakota, Inyan Kara-Sundance, and Minnelusa-Madison, (Hamilton 1986a). These aquifers play an important role in supplying water for consumption and irrigation for the area.

Glacial Aquifers. When a thick ice sheet melted in the area, deep, wide channels were carved in bedrock. Sand and gravel was deposited by the meltwater at shallow depths along the Missouri River, forming glacial aquifers (Hamilton 1986b). The Missouri River aquifer is a two to three mile wide river-channel deposit of alluvium and outwash sand and gravel that underlies 70 mi² in the Pierre area to depths from 0 to 200 feet (Figure 2.6). The majority of the aquifer is within the Missouri River floodplain and is hydraulically

connected to the river. The average saturated thickness is 30 feet. Water movement in the Missouri aquifer moves towards the Missouri River from recharge areas along the floodplain and adjacent terraces. High ground water has been a common occurrence in the lower lying lands along the Missouri River, especially in southeast Pierre. Lateral recharge induced from the river to the Pierre municipal wells occurs, allowing the aquifer to supply more wells because of the potential recharge generated from the river (Hamilton 1986a).

Figure 2.6. Location of major glacial aquifers in Hughes County, South Dakota (Hamilton 1986b).



Bedrock Aquifers. The Dakota aquifer is the uppermost bedrock aquifer in the Hughes County. It is composed of up to 430 feet of very fine to medium-grained sandstone, and is overlain by about 1,000 feet of relatively impermeable shale. The aquifer generally yields 2 to 500 gpm

of water to wells at depths between 800 and 1800 feet. Recharge of the aquifer occurs mainly from upward leakage from deeper aquifers (Hamilton 1986a).

The Inyan Kara-Sundance aquifer lies below the Dakota aquifer and is composed of as much as 180 feet of fine to medium grained sandstone, siltstone, and shale. The majority of the aquifer's recharge occurs from natural upward leakage from the Minnelusa-Madison aquifer which lies below the Inyan Kara-Sundance aquifer. The effect of Inyan Kara-Sundance aquifer development is large because of the large leakage upward due to development of the Dakota aquifer (Hamilton 1986a).

The Minnelusa-Madison aquifer is composed of an average of 400 feet of sandstone, limestone, and dolomite and is the deepest of the bedrock aquifers. Recharge of the aquifer is from precipitation, and from stream flow where the aquifer crops out in the Black Hills of western South Dakota. Discharge is through flowing wells and by leakage upward into the Inyan Kara-Sundance aquifer (Hamilton 1986a).

The area's water quality varies depending on its sources; generally the surface water is classified as fresh, while ground water sources are classified as slightly saline. The Missouri aquifer is generally classified as fresh to saline, while the bedrock aquifers are slightly saline. The deeper aquifers have elevated concentrations of hardness in the water from dissolved calcium and magnesium. In general, the quality of the water decreases as the depth increases, with hardness and salinity most apparent in the deepest aquifers. Missouri River surface water is of suitable quality but requires treatment due to federally mandated treatment regulations and to susceptibility to pollutants. Most ground water is slightly saline, but suitable to many uses. Glacial and bedrock aquifers will likely need treatment to decrease the concentrations of hardness in the water (Hamilton 1986a and Ulteig 2007).

Floodplains

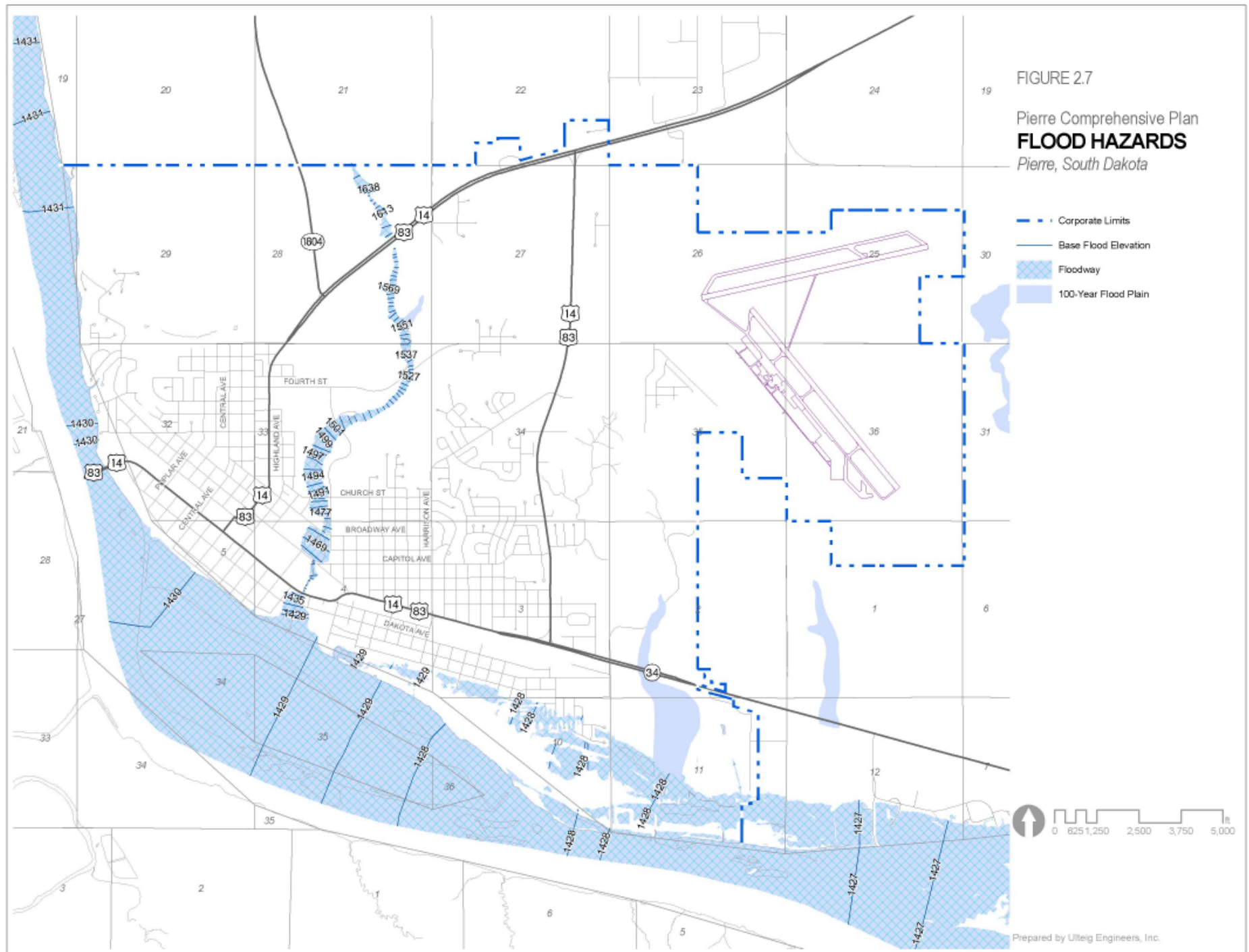
Some land along the Missouri River in the Pierre area is subject to flooding. The United States Army Corp of Engineers and FEMA have identified areas in a 100 year floodplain as illustrated in Figure 2.7. The current effective Flood Insurance Rate Maps are dated May 17, 2004. Ice build up on the Missouri River near Pierre has been a long term phenomenon. Ice cover can result in water surface stages 3 to 4 feet

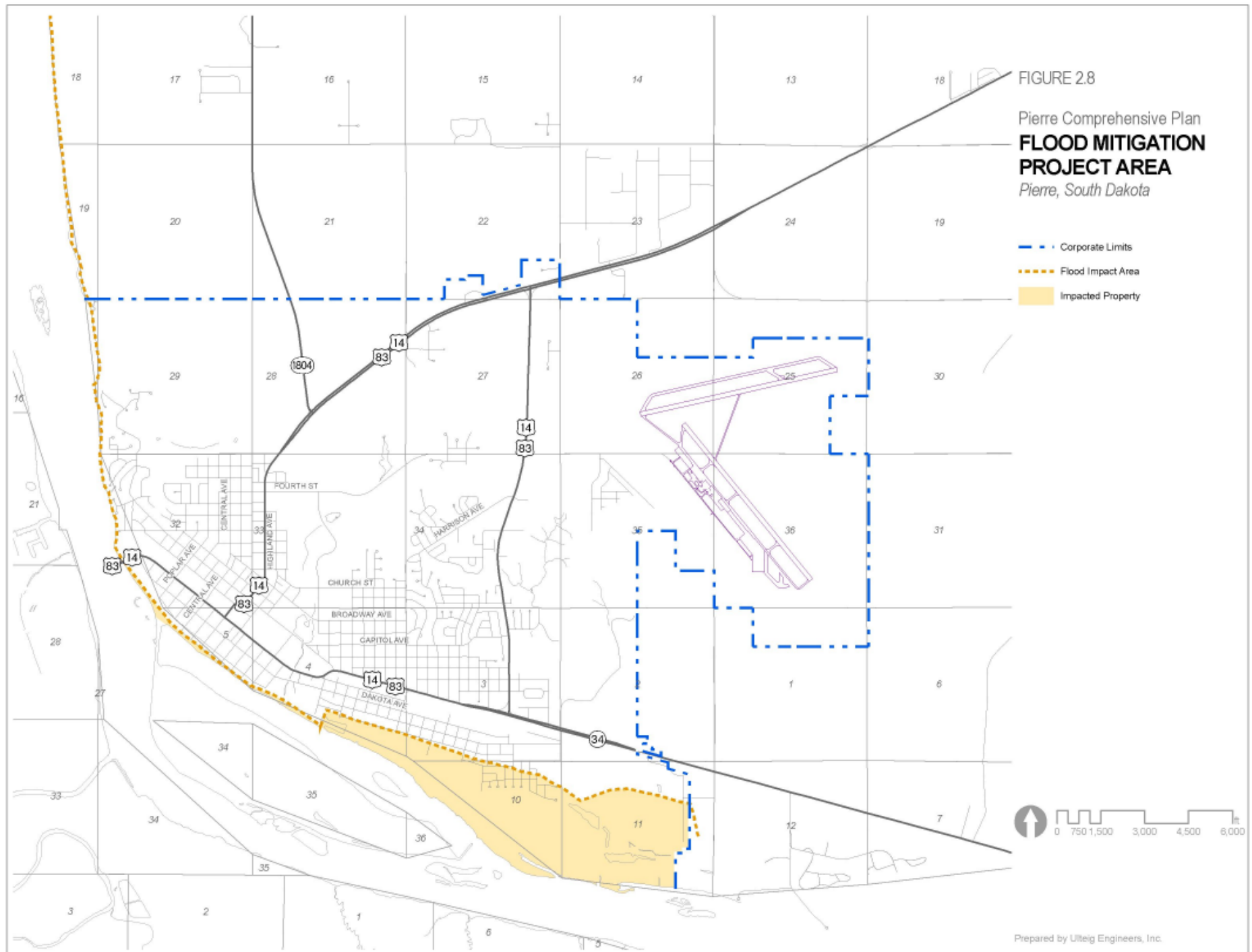
higher than the same Oahe Dam discharge under open flow conditions. Furthermore, sediment build up from the Bad River has significantly reduced Missouri River channel capacity. This increases the frequency and duration when ice build up requires discharges from Oahe Dam to be constrained. Minor ice affected flooding has occurred in the Pierre area in 1979, 1981, 1983, 1994, and 1997. This flooding has lasted from 1 to 10 days. Impacts of this flooding have included:

- High water backing up into storm sewers and onto low lying streets in southeast Pierre
- Access problems to homes
- Vehicles frozen to streets
- Reduced electrical output of Oahe Dam during peak demand times. (USACE 1999)

Projections of future sedimentation and vegetation encroachment indicate that the open water releases of Oahe Dam will be significantly constrained in order to maintain an operational buffer below top of bank of the Missouri River in the Pierre area. In 1998, Congress authorized a project to respond to the impacts of these present and future conditions. This project included purchasing, flood proofing, and relocating privately owned structures in southeast Pierre (USACE 1999). The project area is identified in Figure 2.8. The result of this project is that a large area in southeast Pierre was partially vacated and will only be available for certain types of land uses.

The Federal Emergency Management Agency (FEMA) updated the Flood Insurance Rate Map (FIRM) for Pierre effective May 17, 2004. In order to proactively manage flood-prone areas the City enacted two ordinance changes in April of 2006. The first change required that structures be elevated a minimum of two feet above base flood elevation (BFE) rather than just above the BFE. The second change increased the existing minimum floor elevations for new construction and renovation by 2-3 feet. The changes were based upon maps provided by the U.S Army Corps of Engineers that indicate the 100 year open water future BFE and the 100 year open water future flood boundary by the year 2047. The maps illustrating these areas are included in Appendix 1, and the general areas affected by the future open water flood boundary are illustrated on Figure 2.8.





Climate

Climate is the average weather in a location over a long period of time. Despite the recent weather over the last 6-7 years, there has still been more precipitation overall than in the early part of the 20th century across nearly the whole state of South Dakota. Therefore the weather patterns which constitute “normal” climate are best reflected by the approximately 30 year averages provided by the South Dakota State Climatologist’s office.

Pierre’s varying precipitation and temperature is very typical of central South Dakota (Figures 2.9 and 2.10). Pierre is located in the temperate zone and is characterized by hot dry summers and moderate winters. Seasonally, Pierre’s temperature ranges from highs well over 100°F in the summer to winter temperatures below zero (Hamilton 1986). The majority of precipitation occurs during the growing season and averages 19.88 inches between 1971 and 2000.

The windiest conditions occur in winter through spring with the strongest winds occurring in April when they average around 12.47 mph (Figure 2.11). The prevailing winter winds are from the northwest (Figure 2.12). Typically, midsummer accounts for the calmest conditions with winds prevailing from the southeast (Figure 2.13).

Characteristics of local climate include:

- Temperatures range from a typical low of -30° F in January to typical highs of 97° F in August.
- Average annual temperature for the last 30 years is 47.5° F
- Average annual wind speed is 11.35 mph
- Average January temperature is 17.8° F and average July temperatures is 75.5° F
- Annual precipitation is 19.8 inches
- The month of June has the highest average precipitation of 3.49 inches
- The average annual snowfall is 32.9 inches
- Sunshine in Pierre occurs during 63% of available sunshine hours

Figure 2.9. Normal temperature (°F) reported at Pierre Municipal Airport, 1971-2002 (SDSU Climate and Weather).

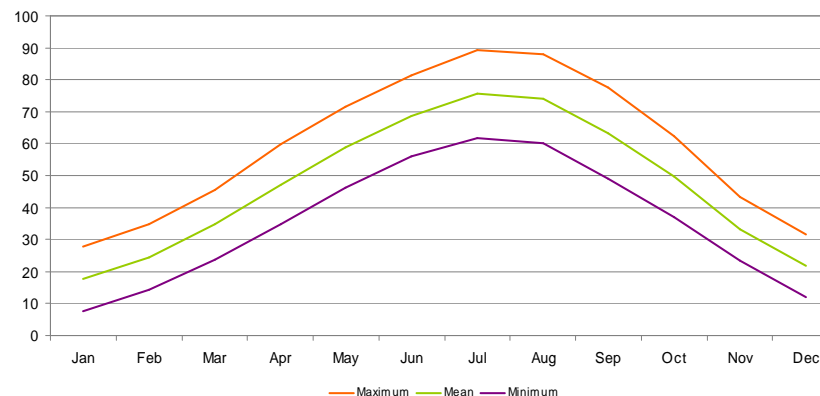


Figure 2.10. Normal precipitation (inches) reported at Pierre Municipal Airport, 1971-2002 (SDSU Climate and Weather).

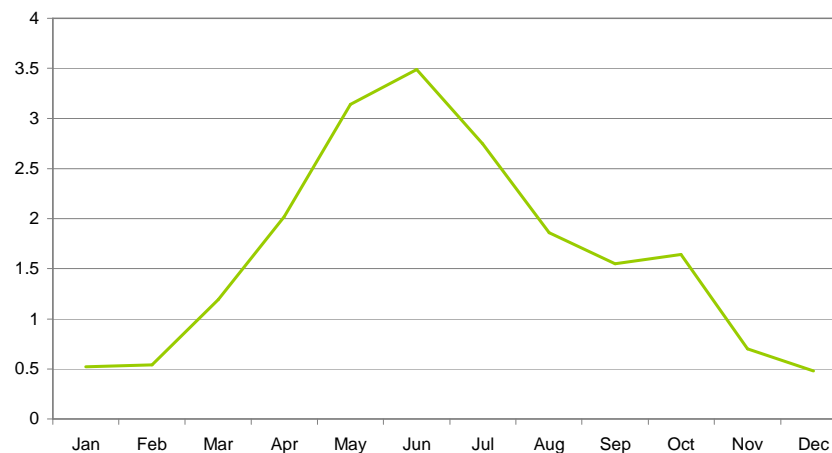


Figure 2.11. Average wind speeds reported at Pierre Municipal Airport, 1971-2002 (SDSU Climate and Weather).

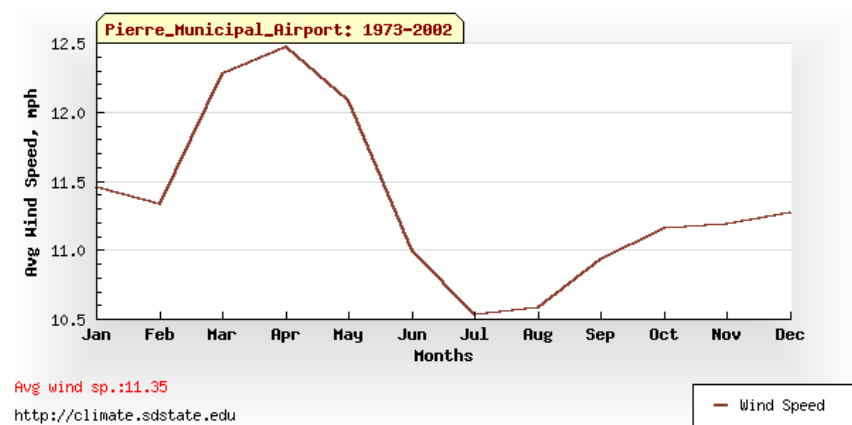


Figure 2.12. Wind direction and speed reported at Pierre Municipal Airport for January, 1973-2002 (SDSU Climate and Weather)

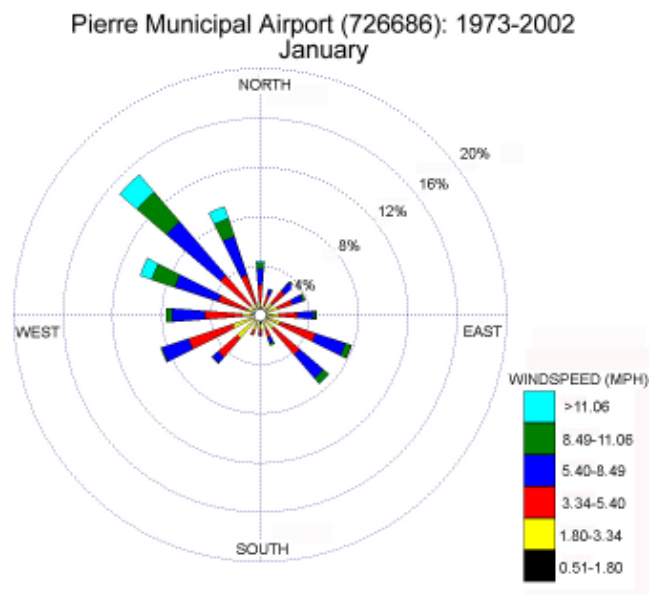


Figure 2.13. Wind direction and speed reported at Pierre Municipal Airport for August, 1973-2002 (SDSU Climate and Weather)

